Introduction

Climate change is widely regarded to be one of the major challenges of the 21st century. Human activities are shifting the balance of the global climate system. The increased concentrations of greenhouse gases (GHGs) like carbon dioxide (CO_2) methane (CH_4) nitrous oxide (N_2O) together with other changes in the climate system increase the global average temperature. In the current scenario of climate change, agriculture lands especially wetland rice fields are considered to be potential sources and sink for various greenhouse gases. Wetland characteristics lead to the accumulation of organic matter in the soil and sediment, serving as carbon (C) sinks and making them one of the most effective ecosystems for storing soil carbon. It has been estimated that different kinds of wetlands contain 350-535 Gt C, corresponding to 20-25% of world's soil organic carbon. However, long term storage is often limited by rapid decomposition processes and release of C to the atmosphere from paddy fields due to various unsustainable practices. Though rice agriculture is inevitable on local and regional basis, existing high input agricultural practices results numerous concerns including soil carbon loss and emission of green house gases. It is crucial to devise ways and means to uphold sustainable cultivation practices as a climate change tool that could be one of the most powerful strategies in the fight against global warming. Since any intervention that encourages conversion from a lower to a higher carbon-storing system will contribute to net carbon storage, the possibilities of organic farming methods are quite promising from a climate change perspective.

At this juncture the possibilities of biochar application as a better rice soil amendment have been experimented in the present work with an aim to increase soil fertility, carbon sequestration potential, green house gas emission reduction and to reduce the negative effects of rice-based wetland systems on global climate. Biochar is a carbon-rich product obtained when biomass is heated in a closed container with little or no available air. Different soil carbon parameters were considered as indicators to depict the carbon transition occurred under biochar application in the wetland rice soil during the study. The management of rice agriculture for positive climate impact must

consider the combined effects of carbon storage and soil greenhouse gas emissions; hence the present study was carried out to examine the potential of biochar application as a sustainable management option in wetland rice-cultivating areas like Kuttanadu.

Objectives

General objective

To study the Carbon and green house gas dynamics of wetland rice soil with special reference to biochar application.

Specific objectives

- Assessment of baseline soil C transition of selected portion of the Kuttanadu wetland rice cultivating tract.
- To study the role of selected environmental variables and factors on wetland soil C transition
- To study the impact of organic and inorganic fertilizer application on rice soil carbon dynamics
- To study the characteristics and potential of six different biochars in rice soil
- To study the effect of character enhancement of a selected biochar

Methodology

The methodology consists of an appraisal phase for assessing baseline loss or accumulation of soil organic carbon and also experimental microcosm studies. Since the organic carbon content dominates the total carbon pool by about 84 to 97 %, the present study focused on the organic carbon part only. Baseline study was done as per the methods prescribed by IPCC (2006). For the baseline soil C study samples from a

depth of 30 cm were collected from different sites of kuttanadu rice cultivating tracts of Kerala. Apart from field study, microcosm studies using pot trials were conducted for assessing the role of various environmental variables, impact of selected weeds like *Echinochloa crus-galli* (L.)P. Beauv, *Oryza rufipogon* Griff. and *Eichhornia crassipes* (Mart.) Solms and the effect of chemical and organic fertilizer on rice soil carbon dynamics. A comparative study on the effect of various biochars and the synergetic effect of selected biochar and Arbuscular mycorrhizal fungi (AMF) on rice growth and soil carbon dynamics was devised under microcosm study. Six different types of biochars selected for the comparative microcosm studies were prepared traditionally from materials like cow dung, rice husk, coconut husk, coconut shell, rubber seed shell, and *Eichhornia* using mount kilns. Soil used for the microcosm study was collected from the experimental plot of Maniyaparambu (9°38'39.03" N, 76°28'58.64"E), a part of the Kuttanadu rice cultivating tract. The major parameters considered are soil organic carbon (SOC), its labile and recalcitrant fractions, particulate organic carbon (POC), potential carbon mineralization (PCM), microbial biomass carbon (MBC), soil green house gas emissions in terms of CO_2 and N_2O and their subsequent global warming potential as well as growth profile studies of rice plant. Characterization study of biochars were also done using 13 C NMR for analysis of C functional group, EDX for elemental analysis and SEM for obtaining images.

Findings

The appraisal study reveals the baseline soil characteristics especially the soil carbon fractions and dynamics with respect to cultivated and abandoned paddy sites of the selected region in the Kuttanadu wetland ecosystem. Even though the sites show innate wetland characteristics, indiscriminate cultivation activities in terms of intensive fertiliser application, increased tillage, unscientific water management, and other related activities significantly altered the basic carbon source and sink capacity. The soil carbon dynamics depicting the indicators like soil carbon storage, potential carbon mineralisation and carbon turn over, the cultivated sites are found to be vulnerable carbon pool contributing substantially towards regional global warming. These findings points towards the current unsustainable cultivation practices which

need to be corrected at the earliest. Thus the present study depicting the baseline has of due importance upon which future inferences can be made.

Ex-situ growth experiments evaluated the fate of paddy soil under different conditions and the role of agricultural practices in soil and vegetation carbon sequestration without compromising productivity and thereby promoting the ways of sustainability. Considering all the applied trial conditions and parameters it can be suggested that a soil with neutral pH, subjected to intermittent flooding and draining is favorable from a carbon sustainable view point without compromising productivity. In case of trial with weeds [*Echinochloa crus-galli* (L.)P. Beauv, *Oryza rufipogon* Griff. and *Eichhornia crassipes* (Mart.) Solms] maximum soil and biomass carbon sequestration potential was observed. From this it can be inferred that during the fallow periods weed growth is beneficial from a carbon sequestration view point.

The experimental microcosm study to depict the role of organic and inorganic amendments on soil C transition indicates the positive effects of organic amendments over chemical fertilisers in terms of soil carbon fractions and productivity optimisation from a climate change perspective. Experimental results of organic amendments especially biochar increased the chemical, physical and biological properties of rice soil thereby improving soil fertility. The improvement of soil properties with organic soil amendment applications resulted in an improvement of rice growth as shown by an increase in plant height, number of tillers, dry biomass and grain yield. Viewing the results from a sustainable carbon perspective the results are not satisfactory in the case of chemical fertiliser application. Furthermore the emission status in terms of CO_2, N_2O and subsequent GWP, chemical amendments were found to be highly deleterious since considerable amount of soil based emissions were identified. The study indicates that application of biochar increased the maximum allocation of carbon both in the soil and biomass, thus portraying its C sink capacity. The application of organic amendments, especially biochar is found to be more preferable. The result indicates the importance and need of a shift in the high input agriculture practices to a cost effective sustainable system. A conversion to organic agriculture practices with biochar application can help in restoring the system

resilience without comprising the food productivity. Hence it is imperative to prefer sustainable agricultural practices for attaining maximum yield without affecting the climate system. In this context, the possibilities of biochar production and application may be viewed and practiced under a sustainable approach.

Biochar characterization studies show that it is comprised of stable carbon compounds created when biomass is heated to temperatures between 300 to 1000°C under low (preferably zero) oxygen concentrations. The structural and chemical composition of biochar is highly heterogeneous, with the exception of pH, which is typically > 7. Some properties are pervasive throughout all biochars, including the high C content and degree of aromaticity, partially explaining the high levels of biochar's inherent recalcitrance. Nevertheless, the exact structural and chemical composition, including surface chemistry, is dependent on a combination of the feedstock type and the pyrolysis conditions (mainly temperature) used. Biochar's physical and chemical characteristics may significantly alter key soil physical properties and processes and are, therefore, important to consider prior to its application to soil. Dissimilarities in properties between different biochar products emphasizes the need for a case-by-case evaluation of each biochar product prior to its incorporation into soil at a specific site.

The application of different biochars significantly altered the physical and chemical properties of the soil. Biochars prepared from coconut shell and *Eichhornia* are found to be more effective in producing favorable result in terms of soil pH, CEC etc. Owing to this both these biochar could be used as a substitution for lime materials to increase the pH of acidic soils of Kuttanadu. Considering the pH values of all biochars most of them are proved to be effective liming agent capable of neutralizing pH values. The N, P and K retention and availability in the soil was comparatively higher under all the biochar trials. Maximum nutrient retention was observed under *Eichhornia* biochar trial followed by cow dung. Studies suggest that biochar application to soil will affect nutrient leaching. The biological properties of the soil was also enhanced under coconut shell biochar application. Thus the application of biochars especially that of coconut shell and *Eichhornia* significantly altered the soil properties. With respect to

soil C and its counterparts also both these chars were found to be highly sustainable. In terms of SOC and POC the application of rubber seed shell biochar was also highly effective. In case of emission reduction *Eichhornia* biochar was found to be more effective. The productivity optimisation is also achieved under these chars. Hence the coconut shell, rubber seed shell and *Eichhornia* biochars are found to be highly effective and these results can be attributed to the characteristic features of these biochars.

Conversion of *Eichhornia* biomass to biochar and application of the biochar to soil can turn the hitherto waste weed into useful material for soil carbon sequestration and for improving soil fertility. The biochar inoculation with Arbuscular mycorrhizal fungi (AMF) indicated the possibility of a preferable soil amendment which helps to promote sustainable rice agriculture for a region like Kuttanadu. In terms of soil carbon storage and emission reduction, the combination turned out to be a real sustainable tool to combat climate change. The application of this combination in the rice soils can achieve C sustainability to the Kuttanadu rice soil system. Moreover the results of the crop productivity under the trial indicated to help save the rice production area from the peril of chemical fertilizers. Yield optimization can be achieved using this amendment. Moreover the application also helps to tackle the problem of weed management in the Kuttandu rice ecosystem.